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8 Effect of Selenium on Growth, Physiological Aspects and Productivity of Faba Bean (*Vicia faba* L.)

M. S. Boghdady, E. M. Desoky#, S. N. Azoz* and Dalia M.A. Nassar*
*Department of Agricultural Botany, Faculty of Agriculture, Zagazig University, Sharkia and.*Department of Agricultural Botany, Faculty of Agriculture, Cairo University, Giza, Egypt.*

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THIS WORK was conducted during the two successive winter seasons of 2014/ 2015 and 2015 / 2016 at the Agricultural Experiments and Researches Station (Ghazala Farm), Faculty of Agriculture , Zagazig University , Sharkia Governorate, Egypt, to study the effect of foliar spray with selenium at concentrations of 0, 2.5 , 5 , 10 , 15 and 20 ppm on growth, chemical composition , yield as well as anatomy of stem and leaves of faba bean cv. Giza 716. The experimental results showed that foliar application with 20 ppm selenium showed no effect on vegetative growth , yield components ,seed quality, photosynthetic pigments (chl a , chl b, total chl and carotenoids) concentration, carbohydrates fractions , minerals and crude protein percentage. Foliar application with 10 ppm selenium significant improvement effects on vegetative growth , yield, seed quality, photosynthetic pigments, carbohydrates fractions, minerals and crude protein percentage of faba bean cv. Giza 716. Foliar application with 10 ppm selenium induced favorable enhancement in anatomical feature of stem and leaves. Exogenous application of selenium also induced prominent increase in diameter of stem, thickness of cortex, number of cortical layers, average length and width of vascular bundle, average vessels number per vascular bundle and average diameter of vessel . Likewise, increased thickness of both midvein and lamina, increased thickness of mesophyll size of midvein bundle, length and width of midvein bundle and vessel diameter were increased as a result of spraying selenium.

Keywords: Faba bean, Selenium, Anatomy , Growth , Photosynthetic pigments, Seed quality.

INTRODUCTION

Faba bean is *(Vicia faba)* is classified the first food legume crop in Egypt. Pulses have a wide variation in their nutrient content and contain 55-63% carbohydrates , 18-32% protein, 2-3.5% mineral matters , 0.5- 5.6 % fat ,250-500, 5-10 and 75-280 mg^{-1} 100 g of eatable portion, respectively of phosphorus, iron and calcium. Pulses are also a fairly good source vitamins (Aykroyd & Doughty, 1973; Gopalon *et al.,* 1977 and Gupta , 1982). Cultivation of legume is beneficial to other crops through multiple agro-ecological services increased soil fertility by biological nitrogen fixation and Increase soil content of nitrogen (Nasser *et al.,* 2016; Bargaz *et al.,* 2016 and Kumar *et al.,* 2014) .Faba bean (*Vicia faba* L.) is a main legume and seed is consumed by humans all over the world. Some varieties are remarkable livestock feed and used for fodder, hay, straw and silage (Prolea, 2014). When faba beans are prepared for cattle feeding, small-seed varieties with low-tannin, low vicine-convicine and low-trypsin restraint contents are preferred (McVicar *et al.,* 2013). Faba bean is an alternative to soybeans as a source of protein in cattle feed in Europe (Blair, 2007; Jezierny *et al.,* 2010 and Smith *et al.,* 2013). We can used Faba bean plants to make delicious silage (McVicar *et al.,* 2013). Straw of Faba bean is valued and estimated economic crop in Sudan and Egypt (Muehlbauer & Tullua, 1997). In Sweden, it was used to produce biogas and bioethanol (Petersson *et al.,* 2007). Faba bean grown for the production of green manure (Muehlbauer & Tullua, 1997 and McVicar *et al.,* 2013).

Selenium (Se) has antioxidant properties so that it is necessary for humans and animals (Fairweather-Tait *et al.,* 2011). Selenium is

Corresponding aurhor email: desoky_s@yahoo.com
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trace elements needed by the animal and human (Chaudhary *et al.,* 2010). The lack of this element can cause numerous diseases such as many types of cancers and heart disease (Rayman, 2002). Selenium deficiency affects badly on human health, almost more than 40 types of diseases have been found to be associated its deficiency, such as cancer, liver disease, cardiovascular disease and cataracts (Tapiero *et al.,* 2003 and Cox & Bastiaans, 2007). Se is absorbed and created within the plant in the same assimilation pathway as S, which is present in sulfur amino acids such as selenomethionine and selenocysteine (Sors *et al.,* 2005). Se at low doses are considered an antioxidant, whereas at higher doses are considered a pro-oxidant in plants (Hartikainen *et al.,* 2000). Selenium is a trace element and recognized as a substantial element and toxic reagent for animals including humans (Burke & Opeskin, 2002 and Klein, 2004). However, toxicity of selenium not depends on the chemical form and concentration of selenium in environmental and biological systems (Brown & Arthur, 2001and Li *et al.* 2010). Generally, the inorganic types of selenium such as selenate (SeVI) and selenite (SeIV) have more toxicity at higher doses (Mazan *et al.*, 2002 and Orero *et al,* 2004). Meanwhile, the organic types of selenium, selenomethionine (SeM) ,selenocysteine (SeC) and Se-methylselenocysteine (SeMC) are amino acid forms of selenium in organisms and have abundant benefits for health (Bock *et al.,* 1991 and Hartikainen, 2005). Recommended dose intake of Se is 50 and 90 mg per day^{-1} for men and women, respectively (Alexander *et al.,* 2005) . Terry *et al.* (2000) indicated that, toxic levels of Se for plants depends on plant species and form of Se applied.

Faba bean is consider important food crops in Egypt. In recent times there was a significant gap between production and consumption. Therefore this crop had been chosen to study the effect of exogenous application of selenium at different concentrations on growth parameters, some physiochemical, anatomy and yield of faba bean cv. Giza 716 under Egyptian conditions.

MATERIALS AND METHODS

This work was carried out during the two successive winter seasons of 2014/ 2015 and 2015/ 2016 at the Agricultural Experiments and Researches Station (Ghazala Farm), Faculty of Agriculture , Zagazig University , Sharkia Governorate , Egypt , to study the effect of foliar spray with selenium on growth, chemical composition and yield as well as anatomy of stem and leaves of faba bean cv. Giza 716 grown in clay loam soil. The physical and chemical analyses of the experimental soil is presented in Table 1.

Selenium was sprayed at concentrations of 0, 2.5 , 5 , 10 , 15 and 20 ppm. The control plants were sprayed with tap water. These treatments were arranged in a randomized complete block design with three replicates.

The seeds of faba bean cv. Giza 716 were sown on 5th November in both growing seasons, after inoculation with root nodules bacteria (*Rhizobium leguminosarum*). Plot area was four rows with 3 m length, 50 cm apart and hills were spaced at 50 cm distance. Two seeds were sown in each hill, and then thinned to one plant/ hill. One row was left between each two experimental units as a guard row to avoid the overlapping of spraying solution of selenium. One row was used for samples to measure vegetative growth and the other three rows were used for yield determination.

The source of faba bean cv. Giza 716 was Legume Research Department, Field Crop Institute, Agric. Res. Center, Egypt. The source of root nodule bacteria was the General Organization for Agriculture Equalization Fund (G.O.A.E.F.), Ministry of Agriculture, Egypt. Selenium obtained from Multivita Company, 6 Octobar, Egypt. It is powder with active ingredient 99 % . Faba bean plants were sprayed with solution of selenium two times for each used concentration at 30 and 45 days after sowing. Each plot received 1.5 liters in the first application and 2.50 liters in the second one. This volume was adequate to wet plants of the plot thoroughly, and excess solution was dripping. Tween 20 at 0.5% was used as wetting agent.

The source of nitrogen, phosphours and potassium were ammonium sulphate (20.5%N), calcium superphosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O), respectively. Fertilizer application and cultural operations followed the normal practices of faba bean cultivation.

Climatic data

In the first season (2014 / 2015), daily temperatures ranged from 15.2º – 21.8ºC, with an average of 18.0º ± 2.5ºC. The daily relative humidity averaged 58.0 ± 4.2%, and ranged from 30 – 75%. In addition, the daily temperatures ranged from 13.8º – 20.8ºC, with an average of 17.3º ± 2.8ºC, and the daily relative humidity

TABLE 1. **Physical and chemical properties of the experimental soil (season 2014/ 2015).**

Particle size distribution in %		Chemical (mg/100 g soil)			
Sand	26.71	pH	7.26	Ca++	0.06
Silt	31.63	EC mmohs/cm	1.32	Mg++	0.02
				Na+	0.21
Clay	41.66	Total N%	0.04	CO_3^-	-
Soil texture	Clay loam	Total P%	0.05	HCO_3	0.10
				Cl^-	0.09
Field Capacity %	31.86	Total K%	0.027	SO_4^-	0.10

averaged 56 ± 6.6% and ranged from 28 – 77% in the second season (2015 / 2016).

The data recorded were as following:

Vegetative growth character

A random sample of nine plants was randomly taken from each treatment, 3 plants from each replicate at 90 days after sowing and the following data were recorded:

1- Plant height (cm)
2-Number of branches / plant.
3- Number of leaves / plant.
4- Fresh weight of shoot (g/plant).
5- Dry weight of shoot (g/plant).

Photosynthetic pigments

For all treatments, photosynthetic pigments were determined quantitatively in upper most leaves developed on the main stem at the age of 90 days from sowing date. For this purpose, a random sample of three plants was taken for investigation in each treatment. Photosynthetic pigments (chlorophyll a, chlorophyll b and carotenoids) were extracted by using dimethyl formamide and determined according to Nornai (1982) as mg/g fresh weight of faba bean leaves.

Yield and its components

A random sample of twelve plants was taken from each treatment, 4 plants from each replicate at 150 days after sowing and the following data were recorded:

1. Average number of pods/ plant.
2. Average number of seeds/ plant.
3. Weight of 100 seeds (g).
4. Yield of seeds (g)/ plant.

Chemical analysis in seeds (seed quality)

Minerals content in seed

A known weight (0.2 g) of well mature dried seeds from each treatment in each replicate of plants grown in the first and second seasons were digested in H_2SO_4 (concentrated), H_2O_2 (5:1) for chemical analysis of minerals: nitrogen (N), phosphorus (P), potassium (K) according to A.O.A.C. (1999). The concentration of the N, P, K nutrients were expressed in %. Nitrogen content of seeds was multiplied by 6.25 to calculate the crude protein content (A.O.A.C., 1999).

Selenium concentration

Selenium estimated in mature dried seeds from each treatment in each replicate of plants grown in the second season of 2015/2016 according to Advanced Microwave Digestion was used for digestion of samples. The concentrations of pervious element in various treatments were determined by using Inductively Coupled Plasma- Mass Spectrometer (ICP\MS), NEXION 300X series. Argon gas was used for excitation of the element atom. The blank values for each element were deduced from the sample values. Selenium was expressed in ppm.

Carbohydrates fractions

Carbohydrate fractions was determined according by the method described by Bernfeld (1955) and Miller (1959).

Anatomical studies

A comparative micro-scopical examination was performed on plant material for treatment which showed remarkable response. In addition to the control, tested materials included the main stem at its median portion and leaflet from the compound leaf developed on the median portion of the main stem. Specimens were taken throughout the second growing season of 2015/2016 at the age of 8 weeks. Specimens from control and chosen treatment, including stems and leaves, were killed and fixed for

at least 48 h. in F.A.A. (10 ml formalin, 5 ml glacial acetic acid and 85 ml ethyl alcohol 70%). The selected materials were washed in 50% ethyl alcohol, dehydrated in a normal butyl alcohol series, embedded in paraffin wax of melting point 56°C, sectioned to a thickness of 20 micrometers (µm), double stained with crystal violet-erythrosin, cleared in xylene and mounted in Canada balsam (Nassar & El-Sahhar, 1998).

Statistical analysis

The obtained data (morphological characters, photosynthetic pigments, yield and seed quality) were subjected to conventional methods of analysis of variance according to Snedecor & Cochran (1982) with using the program COSTAT 6.311. The least significant difference (L.S.D.) for each character was calculated at 0.05 level of probability.

RESULTS AND DISCUSSION

Vegetative growth character

Data presented in Table 2 showed the effect of exogenous application of selenium at different concentrations on vegetative growth of faba bean cv. Giza 716 in two successive winter growing seasons

Plant height

Data presented in Table 2 indicated that all concentrations of exogenous application of selenium except that of 15 or 20 ppm induced significant increase in plant height of faba bean cv. Giza 716 in two seasons. The highest values of plant height was recorded at concentration of 10 ppm selenium, increasing plant height by 43.6 and 40.7% compared to control plants in 2014/2015 and 2015/2016 seasons; respectively.

Number of branches / plant

Results in Table 2 assured that the comparatively lower and higher concentrations of selenium (2.5, 15 and 20 ppm) did not have significant effect on number of branches plant^{-1} of faba bean in two seasons. while moderately concentrations (5 and 10 ppm) significant stimulation in number of branches plant^{-1} in two seasons. Treatment of 10 ppm was the best, improving number of branches plant^{-1} by 60.6 % and 52.7 % more than the control in two seasons, respectively.

Number of leaves/plant

Data presented in Table 2 revealed that the comparatively high concentration of selenium (20 ppm) did not have significant effect on number of compound leaves developed plant^{-1} of faba bean . Plants sprayed with 5,10 and 15 ppm selenium significant improvement in number of compound leaves in two successive seasons. Low used concentration of selenium (2.5 ppm) did not have significant effect on number of compound leaves in first season , but it resulted significant increase in the number of leaves in the second season.The highest values of number of leaves was recorded at treatment of 10 ppm selenium ,being 48.7 and 43.1% more than number of leaves developed over untreated plant in 2014/2015 and 2015/2016, respectively.

Fresh weight of shoot/plant

It is obvious from Table 2 that all adopted concentrations except low used concentration of selenium (2.5 ppm) and high concentration (20 ppm) promoted significantly fresh weight of shoot plant^{-1} of faba bean in two seasons. The maximum significant increase in fresh weight of shoot plant^{-1} was achieved when plants of faba bean were sprayed with 10 ppm selenium ,being 97.6 and 91.1 % more than fresh weight of shoot over untreated plant in the first and second season, respectively.

Dry weight of shoot/plant

It is obvious from Table 2 that exogenous application selenium at all concentrations except that of 2.5 or 20 ppm significant stimulation increase in dry weight of shoot per plant of faba bean. The highest value of the dry weight of shoot per plant was recorded when plants of faba bean were sprayed with 10 ppm selenium ,being 71.3 and 67.8% more than the control plant in the both seasons; respectively.

These results are in conformity with Pennanen *et al.* (2002) where they stated that , plant growth stimulated by selenium is due to increase starch content in chloroplast. The cell can be protected by selenium from oxidative damage by antioxidant defenses (Seppanen *et al.*, 2003). Hasanuzzaman *et al*.(2010) found that, spraying with selenium increased the activity of many enzymes. Malik *et al.* (2011) stated that, shoot growth was enhanced by 24 and 27% in mungbean plants were grown hydroponically in the presence of selenium at 0.5 and 0.75 ppm, respectively. While roots growth increased by 18 and 19%, respectively. Shoot/ root ratio increased and highest effect at 0.75ppm. Boldrin *et al*.(2013) observed that is able to move further through the phloem when

TABLE 2. Effect of exogenous application of selenium at different concentrations on vegetative growth parameters of faba bean plants.

Treatments	Conc. (ppm)	Morphological characters									
		Plant height (cm)		No. of branches/ plant		No. of leaves/ plant		Fresh weight of shoot (g) / plant		Dry weight of shoot (g) / plant	
		First season	Second season	First season	Second season	First season	Second season	First season	Second season	First season	Second season
Control	0.00	44.7	49.8	3.3	3.6	61.6	67.3	175.7	189.2	42.83	46.14
Selenium	2.5	52.9	58.2	3.3	4.1	69.3	77.6	205.8	224.6	49.62	51.92
	5.0	63.1	67.4	4.5	4.9	84.3	89.8	311.3	296.4	68.15	65.66
	10	64.2	70.1	5.3	5.5	91.6	96.3	347.2	361.7	73.39	77.42
	15	49.4	53.9	3.6	3.6	73.8	80.2	261.9	239.2	55.24	57.11
	20	42.5	47.8	3.3	3.3	65.3	61.9	184.5	176.4	45.11	43.84
L.S.D. (0.05)		7.58	8.19	0.92	0.74	9.29	10.13	43.8	50.2	7.13	7.72

it sprayed on leaves, the same easily transported through the xylem when it applied in the soil and absorbed by roots in rice plants. Similar results were also reported by Hawrylak -Nowak (2009) on cucumber and by Turakainen *et al.* (2004) on potato. Kumar *et al*. (2013) and Kumar *et al.* (2014) also recorded increase in morphological parameters of legume crops with spraying of different chemicals at flowering and reproductive stages of crops.

Photosynthetic pigments

The obtained results in Table 3 that foliar spray with selenium at concentrations 15 or 20 ppm did not have significant effect on photosynthetic pigments (Chl a , Chl b, total Chl and carotenoids) concentration in faba bean leaves cv. Giza 716. By contrast, lower and moderately concentrations of selenium (2.5, 5, and 10 ppm) significant enhancement in this respect. The high values of photosynthetic pigments was recorded at 10 ppm selenium, being 54 , 55 , 54.3 and 22.6 % over the control for Chl a , Chl b, total Chl and carotenoids in the first season, respectively and it was 50.8 , 66.6 , 50.3 and 23,8 % more than the control in the second one. These results are in accordance with those reported by Padmaja *et al.* (1989). It was found that ,higher concentration of Se decreased chlorophyll content in mungbean plants. Lower Se concentrations (2 and 6 mg^{-1} L sodium selenite) enhanced photosynthesis, stimulated antioxidative system and primary metabolism. But, higher Se concentration (10 mg/L sodium selenite) reduced photosynthesis and primary metabolism in rice plants (Wang, 2012) Chen *et al*.(2008) reported that, chlorophyll content increased in Alga spirulina by applied selenium. In this concern, Sreekala *et al.* (1999) stated that, mitochondrial oxygen uptake increased by selenium in Trigonelle foenum graecum. Selenium and other chemicals such salicylic acid

TABLE 3. Effect of exogenous application of selenium at different concentrations on Photosynthetic pigments of faba bean plants.

Treatments	Conc. (ppm)	Photosynthetic pigments (mg/g FW)							
		Chlorophyll a (Chl *a*)		Chlorophyll b (Chl b)		Total chlorophyll (Chl)		Carotenoids	
		First season	Second season	First season	Second season	First season	Second season	First season	Second season
Control	0.00	1.11	1.16	0.40	0.36	1.51	1.53	0.62	0.63
Selenium	2.5	1.53	1.48	0.60	0.53	2.13	2.02	0.74	0.73
	5.0	1.70	1.73	0.59	0.55	2.29	2.29	0.75	0.76
	10	1.71	1.75	0.62	0.60	2.33	2.30	0.76	0.78
	15	1.20	1.14	0.53	0.50	1.73	1.64	0.61	0.61
	20	1.14	1.15	0.42	0.43	1.56	1.58	0.60	0.61
L.S.D. (0.05)		0.21	0.25	0.13	0.15	0.35	0.42	0.08	0.09

decrease the disadvantaged free radicals of the chloroplast in plants grown under environmental stress conditions and increase the chlorophyll (Malik *et al.,* 2012 and Kumar & Sarlach, 2015). Se restores transport of metabolites for chloroplast function and reactive membrane enzyme (Filek *et al.,* 2009). Similar trend were also found by Germ & Oswald (2005) on *Eruca sativa*, Germ *et al.*(2007) on potato, Yao *et al.* (2009) on wheat and Moussa *et al.* (2010) on Vicia faba.

Yield characters

Data in Table 4 showed the effect of foliar spray of selenium at different concentrations on faba bean plants in two successive winter growing seasons.

Number of pods/plant

Resulted in Table 4 clearly showed that all assigned concentrations of selenium, except the higher concentration (20 ppm), increased number of pods plant^{-1} of faba bean. The significant increase in pods was recorded at concentrations of 5,10 and 15 ppm selenium in the first season and at concentrations of 5 and 10 ppm selenium in the second season. The maximum significant increase in number of pods /plant was recorded when faba bean plants were sprayed with 10 ppm selenium in both studied seasons, being 79.8 and 84.4 % more than the untreated plant in 2014/2015 and 2015/2016 season, respectively. However, the difference between 5 and 10 ppm selenium proved insignificant in two seasons. By contrast, the higher concentration of 20 ppm selenium enhanced significant decrease in number of pods plant^{-1} of faba bean in two seasons ,being 27.8 and 29.5 % less than the control in 2014/2015 and 2015/2016 seasons, respectively. The information about exogenous application of selenium on the number of pods /plant of faba bean or other related species is meager but it is well documented that bio-regulators spray at higher concentrations in legume crops inhibit photosynthesis and affects yield of plants (Kumar *et al.,* 2013; Kumar *et al.,* 2014 and Kumar & Sarlach, 2015).

Number of seeds/plant

It is realized from Table 4 that all tested concentrations of selenium, except the high sprayed one (20 ppm selenium), increased number of seeds plant^{-1} of faba bean in both investigated seasons. Number of seeds were significantly increased by exogenous application of selenium at concentrations of 2.5 , 5,10 and 15 ppm in the first season and at concentrations of 5 and 10 ppm selenium in the second one . The maximum significant increase in number of seeds/plant of faba bean was observed at 10 ppm selenium in both investigated seasons , being 107.8 and 101.1% more than those of untreated plants in 2014/2015 and 2015/2016 seasons, respectively. It is obvious that the difference between 5 and 10 ppm selenium was not significant in two seasons. On the other hand, high concentration of selenium (20 ppm) induced significant retardation on number of seeds/ faba bean plant in two seasons. The decrease in number of seeds/ faba bean plant less than the control was 27.7% in the first season and 27.3% in the second one.

Weight of 100 seeds

It is noted from Table 4 that all sprayed concentrations of selenium, except that the high sprayed one of (20 ppm selenium), increased specific seed weight of faba bean. The significant increase was achieved at 5 and 10 ppm selenium in the first season and at 10 ppm selenium in the second one. The maximum significant increase in specific seed weight was detected at 10 ppm selenium in both studied seasons, being 12.0 and 8.1% more than specific seed weight of untreated plants in the first and second season; respectively. By contrast, the high concentration of selenium (20 ppm) induced significant decrease in 100 seeds weight of faba bean in two seasons ,being 7.5 and 7.4 % less than the untreated plants in both seasons, respectively.

Yield of seeds / plant

It is clear from Table 4 that all sprayed concentrations of selenium, except that of higher concentration (20 ppm selenium), increased yield of seeds/plant of faba bean in both seasons . The significant increase in yield plant^{-1} was recorded at concentrations of 2.5, 5,10 and 15 ppm selenium in the first season and at concentrations of 5 , 10 and 15 ppm selenium in the second one. The maximum significant increase in seed yield was observed when faba bean plants were sprayed with 10 ppm selenium in both studied seasons, being 132.8 and 117.6 % more than seed yield of the control in 2014/2015 and 2015/2016 seasons; respectively . On the other hand, the high used concentration of 20 ppm selenium induced significant decrease in seed yield in both studied seasons.The decrement below the control was 33.2 % in the first season and it was 32.6 % in the second season. However, Boldrin *et al.*(2013) found that foliar application with

TABLE 4. Effect of exogenous application of selenium at different concentrations on yield components of faba bean plants.

Treatments Conc. (ppm)		Yield characters							
		No. of pods / plant		No. of seeds / plant		Weight of 100 seeds (g)		Seed yield (g) / plant	
		First season	Second season	First season	Second season	First season	Second season	First season	Second season
Control	0.00	19.8	17.3	65.3	57.1	71.54	72.61	46.72	41.39
Selenium	2.5	23.6	19.5	84.9	66.3	73.38	72.94	62.29	48.36
	5.0	34.2	31.7	123.1	107.8	78.92	75.26	97.15	81.13
	10	35.6	31.9	135.7	114.8	80.14	78.47	108.75	90.08
	15	26.5	20.7	95.4	68.3	74.29	73.11	70.87	49.93
	20	14.3	12.2	47.2	41.5	66.17	67.23	31.23	27.90
L.S.D. (0.05)		5.26	4.91	16.82	13.71	5.09	4.66	11.44	8.52

selenium increased grain yield of rice plants, being partially harmony with the present finding. Others workers while working with spraying of higher concentration of bio-regulators in legumes also recorded decrease in yield of crop due to impeding effect on photosynthesis (Kumar *et al.*, 2013; Kumar *et al.,* 2014 and Kumar& Sarlach, 2015)

Chemical analysis of seeds (seed quality)

Minerals and crude protein percentages

Percentages of nitrogen: Results shown in Table 5 revealed that plants treated with concentrations of 15 and 20 ppm selenium had no significant differences in nitrogen percentage of faba bean seeds. On the other hand, plants treated with other concentration gave a significant increase in percentage of nitrogen in both seasons. The highest increase (19.4 %) was recorded at 10 ppm selenium in both seasons.

*Percentages of phosphorus :*It is obvious from Table 5 that all treatments of selenium, except treatment with 20 ppm, increased significantly phosphorus percentage of faba bean. The highest percentage of P was recorded at 10 ppm selenium (51.8 and 33.3 %) than the seeds of untreated plants in 2014/2015 and 2015/2016 season, respectively.

*Percentages of potassium:*Results shown in Table 5 revealed that foliar spray with selenium at concentrations 5 or 10 ppm enhanced significantly potassium percentage in seeds of faba bean in both seasons. while, other used concentrations showed no significant differences on potassium percentage in seeds. The highest percentage was recorded at 10 ppm selenium in both studied seasons.

Crude protein: Foliar application with selenium on crude protein percentage in seeds of faba bean showed the same trend that mentioned before about the effect of selenium on nitrogen percentage. The best crude protein percentage was recorded in seeds of plants sprayed with 10 ppm selenium in both studied seasons.

Selenium concentration: Seed content of selenium increased with increasing foliar application levels of selenium on faba bean cv. Giza 716.

These results agreed with Yang *et al.* (2003) on soybean. Foliar application with Se at 10 and 20 mg Se m^{-2} twice increase intake of selenium in onion, cabbage, garlic and radish (Slejkovec & Goessler, 2005). He *et al.*(2004) showed that, spraying with selenate decreased accumulation of Pb and Cd and stimulated uptake of main elements in Lettuce. Selenium can also reduce the harmful effect of heavy metal on plants (Khattak *et al.,* 1991). Broadley *et al.* (2010) and Pezzarossa *et al.* (2012) found that, foliar application with selenium increased Se content in seeds and fruits of crops. Spraying with selenate and selenite increase Se accumulation in rice grains (Boldrin *et al.,* 2013). Rios *et al.* (2010) observed non significant effect of source and level of selenium on N content in Lettuce plants. Boldrin *et al.* (2013) indicated that, soil application of Se gave higher content of P compared with foliar application on rice. Similar results were also reported by Hu *et al.* (2002) on rice and Poggi *et al.* (2000) on potato.

TABLE 5. Effect of exogenous application of selenium at different concentrations on percentage of N,P,K, crude protein and Se concentration in seeds of faba bean plants.

Treatments	Conc. (ppm)	Nutrients (%)								Selenium conc. (ppm)
		N		P		K		Crude protein (%)		
		First season	Second season	First season	Second season	First season	Second season	First season	Second season	Second season
Control	0.00	3.85	3.96	0.27	0.30	1.64	1.63	24.06	24.75	0.0058
Selenium	2.5	4.41	4.30	0.37	0.37	1.68	1.70	27.56	26.87	0.0079
	5.0	4.55	4.40	0.40	0.39	1.72	1.73	28.43	27.50	0.0115
	10	4.60	4.73	0.41	0.40	1.74	1.73	28.75	29.56	0.0181
	15	4.19	4.09	0.35	0.32	1.67	1.65	26.18	25.56	0.0193
	20	3.99	4.00	0.28	0.30	1.60	1.54	24.93	25.00	0.0204
L.S.D. (0.05)		0.51	0.42	0.031	0.028	0.08	0.09	2.56	2.10	0.0019

Carbohydrates fractions

Total carbohydrates

It is clear from Table 6 that all treatments of selenium, except treatment with 20 ppm, increased significantly total carbohydrates percentage of faba bean seeds in both seasons. The highest percentage was achieved at 10 ppm selenium in two successive seasons.

Total sugar

Exogenous application of selenium at 5 or 10 ppm improved significantly in total sugar percentage in seeds of faba bean in two successive seasons (Table 6). Furthermore, any of the other used concentrations didn't have significant effect on total sugar percentage in seeds. The highest percentage was achieved at 10 ppm selenium in both studied seasons.

Reducing sugar

It is clear from Table 6 that exogenous application with selenium on the percentage of reducing sugar in seeds of faba bean appeared the same trend of the effect on total sugar percentage. The best percentage of reducing sugar was recorded in seeds of plants sprayed with 10 ppm selenium. In this respect, Malik *et al.* (2011) observed that, sucrose content of shoot increased compared with root by selenium application in mungbean .Carbohydrate content of potato increased when plants treated with selenium and starch content of shoot was greater than the root. Increased accumulation in carbohydrates of shoot due to reduction in starch degradation and transport of total carbohydrates to roots as well as stimulated in photosynthesis (Turkainen *et al.,* 2004). Similar results were also observed by Jang & Sheen (1994) .

TABLE 6. Effect of exogenous application of selenium at different concentrations on percentage of carbohydrates fractions in seeds of faba bean plants.

Treatments	Conc. (ppm)	Carbohydrates fractions %					
		Total carbohydrates		Total sugar		Reducing sugar	
		First season	Second season	First season	Second season	First Season	Second season
Control	0.00	56.50	56.60	3.30	3.10	0.46	0.48
Selenium	2.5	57.50	57.70	3.50	3.60	0.54	0.53
	5.0	57.60	57.90	3.90	4.00	0.64	0.66
	10	58.20	58.40	4.10	4.20	0.74	0.70
	15	57.60	57.80	3.80	3.50	0.60	0.60
	20	57.30	57.00	3.25	3.40	0.52	0.48
L.S.D. (0.05)		0.90	0.81	0.50	0.62	0.17	0.15

Anatomical studies

Anatomy of the main stem

Microscopical counts and measurements of certain histological characters in transverse sections through the median portion of the main stem of faba bean as affected by exogenous application of selenium at concentration 10 ppm and untreated plant (control) are presented in Table 7. Also, microphotographs explicating such treatment and control are shown in Fig 1.

It is clear from Table 7 and Fig. 1 that sprayed faba bean plants with 10 ppm selenium increased stem diameter by 12.0% more than that of the control . The increase in diameter of stem was mainly due to the noticeable increment in stem wall thickness by 24.4% over the control, although a negligible decrease of 2.6% below the control in hollow pith diameter was observed. It is realized that the increase induced in thickness of stem wall as a result to exogenous application with 10 ppm selenium could be attributed to the rise in all included tissues. Cortex thickness, number of cortical layers, average length and width of vascular bundle, average vessels number per vascular bundle and average vessel diameter were increased by 42.8, 10.8, 28.0, 22.4, 43.2 and 17.3% more than those of the control; respectively.

Anatomy of leaflet blade

Certain microscopical characters of a leaflet from the compound leaf developed on the median portion of the main stem of faba bean cv. Giza 716 as affected by foliar spray with 10 ppm selenium and those of control were followed up in form of measurements of the transverse sections being given in Table 8. Also, microphotographs explicating such treatment and control are shown in Fig.2.

It is noted that selenium at 10 ppm resulted in leaflets thicker than those of the untreated plant. This impact was attributed to increment in thickness of both midvein and lamina by 29.3 and 24.5% over the control; respectively. Such treatment increased mesophyll thickness and midvein bundle size. Mesophyll thickness was increased by 23.4% over the control. Length and width of midvein bundle were increased by 2.3 and 5.5% over the control; respectively. Diameter of vessel showed prominent increase by 38.4% over untreated plant.

TABLE 7. Effect of selenium at 10 ppm on histological characters in main stem of faba bean .

Histological characters (µm)	Treatments		
	Control	Selenium (10 ppm)	± % to control
Diameter of stem	4387.0	4915.0	+12.0
Thickness of stem wall	1164.0	1448.0	+24.4
Thickness of cortex	321.9	459.6	+42.8
No. of cortical layers	6.5	7.2	+10.8
Dimensions of vascular bundle			
Length	574.8	735.7	+28.0
Width	413.3	505.8	+22.4
No. of vessels / vascular bundle	27.3	39.1	+43.2
Vessel diameter	21.4	25.1	+17.3
Diameter of hollow pith	2066.0	2012.0	-2.6

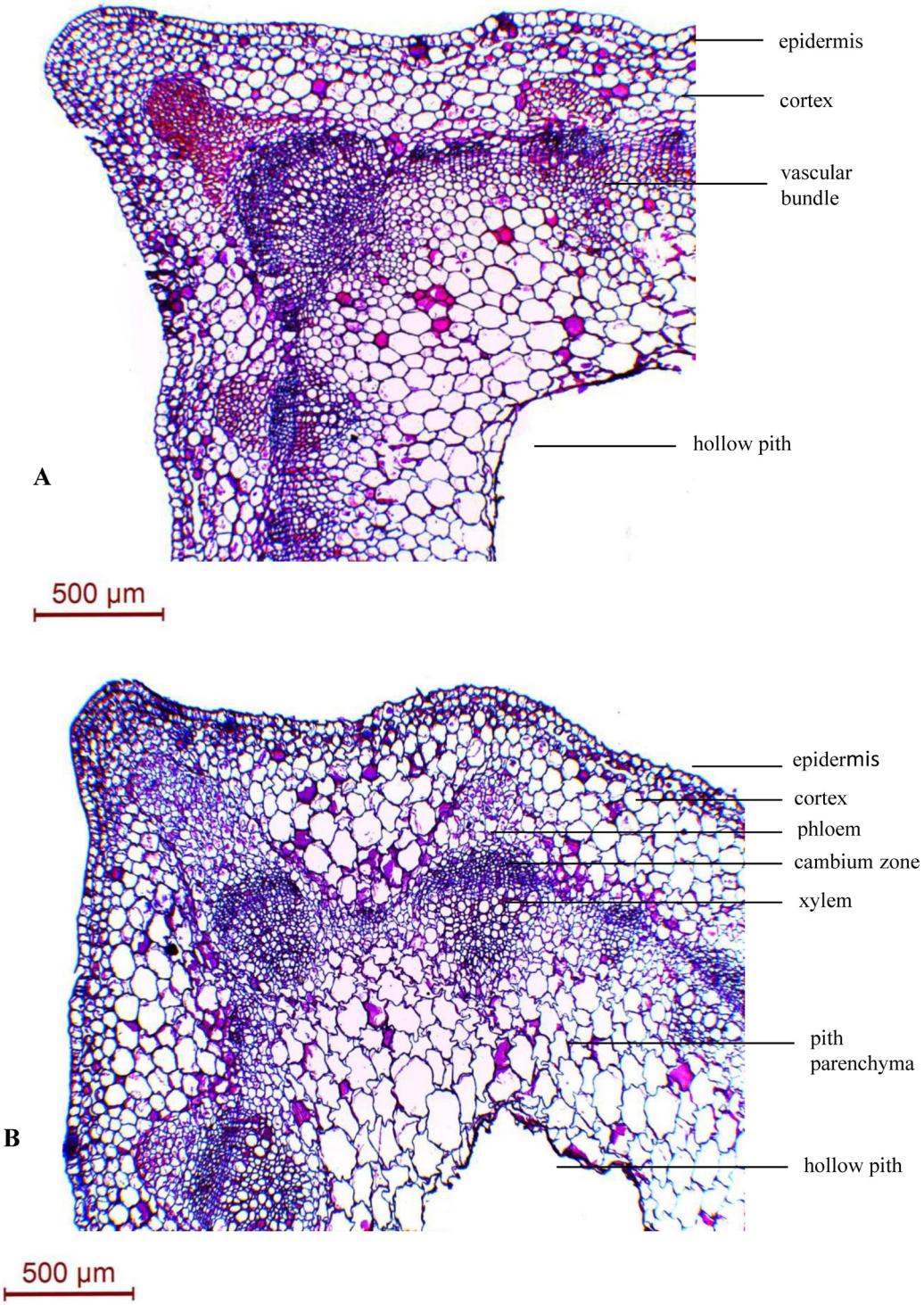

Fig . 1. Transverse sections through median portion of the main stem of faba bean plant, aged 8 weeks, as affected by foliar spray with selenium.
A- From control plant . **B- From plant treated with 10 ppm selenium.**

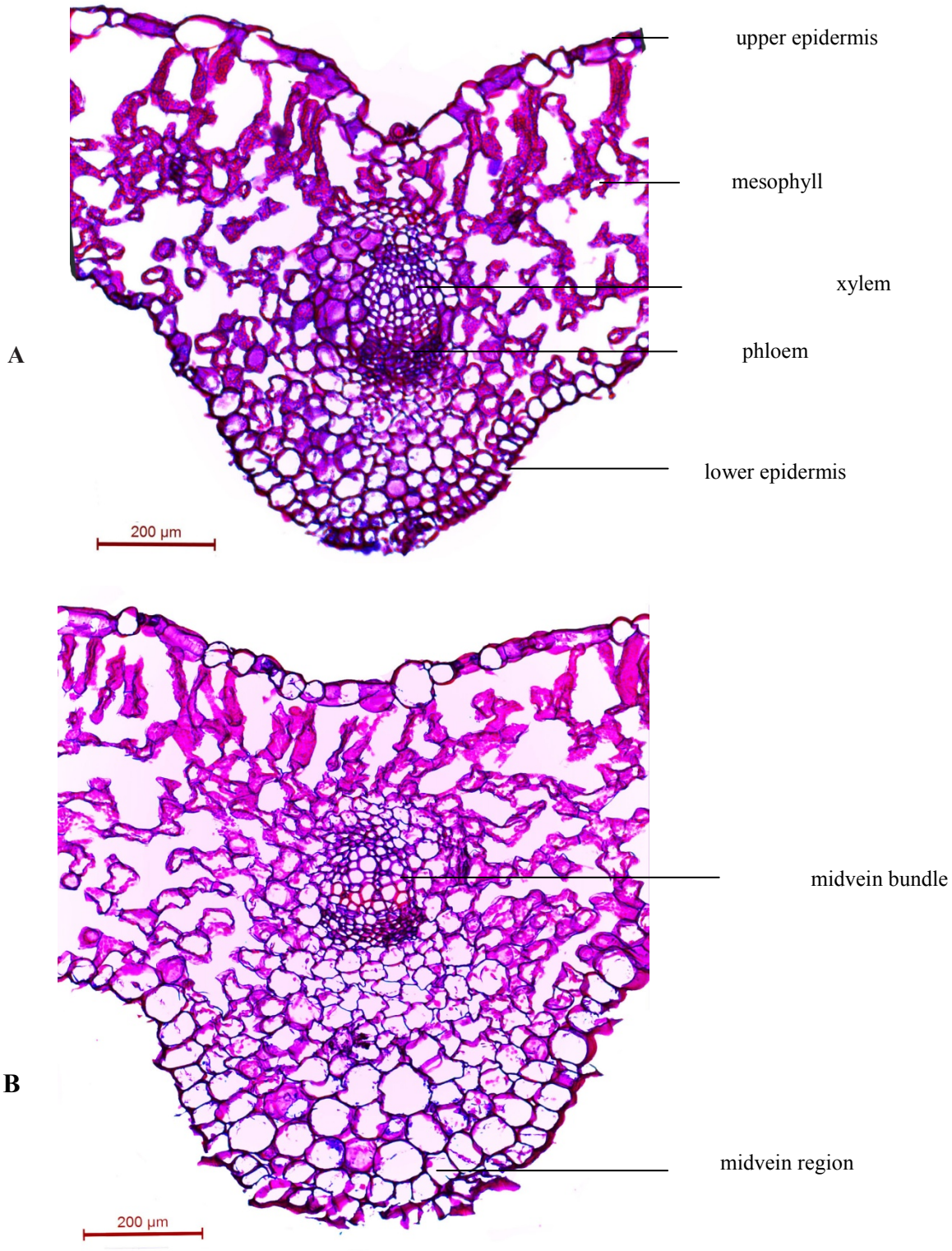

Fig . 2. Transverse sections through lamina of the upper leaflets of the compound leaf developed on the median portion of the main stem of faba bean plant, aged 8 weeks, as affected by foliar spray with selenium.
A- From control plant. B- From plant treated with 10 ppm selenium.

TABLE 8. Effect of selenium at 10 ppm on histological characters in the blades of the upper most leaflets of the compound leaf developed on the main stem of faba bean .

Histological features (μm)	Treatments		
	Control	Selenium (10 ppm)	± % to control
Midvein thickness	710.6	918.9	+ 29.3
Lamina thickness	502.1	625.3	+ 24.5
Mesophyll thickness	445.2	549.5	+ 23.4
Dimensions of midvein bundle:			
Length	208.4	213.2	+ 2.3
Width	156.2	164.8	+ 5.5
Vessel diameter	19.8	27.4	+ 38.4

CONCLUSION

The low concentrations of selenium (5, 10 ppm) used in this study gave positive effects on growth, yield and seed quality. These concentrations have no negative effect on humans and animals. We recommend spraying with a concentration of 10 ppm selenium.

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تأثير السيلنيوم على النمو والمظاهر الفسيولوجية والانتاجية فى الفول البلدي

محمد سليم بغدادى، السيد محمد دسوقى ، سماح نجيب عزوز* و داليا محمد عبدالعزيز نصار*
قسم النبات - الزراعى - كلية الزراعه - جامعة الزقازيق - الشرقيه و** قسم النبات – الزراعى- كلية الزراعه – جامعة القاهرة- القاهره - مصر.

اوضحت النتائج أن الرش الورقى بالسيلينيوم بتركيز 20 جزء فى المليون لم يعطى اى تأثير على النمو الخضري ، مكونات المحصول، جودة البذرة ، صبغات الكلورفيل (أ ، ب ، الكلورفيل الكلى والكاروتنويدات) ، صور الكربوهيدرت، العناصر المعدنية ، ونسبة البروتين. بينما ادت المعاملة بالسيلينيوم بتركيز 10 جزء فى المليون ادت إلى استجابة معنوية على النمو الخضري ، مكونات المحصول ، جودة البذرة ، صبغات الكلورفيل (أ ، ب ، أ + ب) والكاروتنويدات ، صور الكربوهيدرت ، العناصر المعدنية ، ونسبة البروتين.

ادت المعاملة بالسيلينيوم بتركيز10 جزء فى المليون الي احداث تغيرات مرغوبه فى التركيب التشريحي للساق والاوراق. الرش بالسيلينيوم ادى إلى زيادة فى قطر الساق ، سمك القشرة ، عدد طبقات القشرة ، طول وعرض الحزمة الوعائية ، متوسط عدد اوعية الخشب/ الحزمة ، وكذلك قطر الوعاء وبالمثل حدث زياده فى سمك العرق الوسطى ونصل الورقة، سمك النسيج المتوسط ، حجم وطول وعرض حزمة العرق الوسطى ، قطر وعاء الخشب .